Optimization of Inter-satellite Link (ISL) in Hybrid OFDM-IsOWC Transmission System

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***Abstract*— Inter-satellite optical wireless communication system (IsOWC), one of the important applications of FSO (Free Space Optics) technology, will be deployed in space in the near future because of providing power efficient and high bandwidth allocation facilities unlike present microwave satellite systems. In this paper, we have deliberated a novel model of OFDM-IsOWC system using OPTISYSTEM™ simulator to optimize an inter-satellite link (ISL) between satellites with acceptable SNR and BER, which is not reported in previous investigated work.**

***Index Terms*— IsOWC System, ISL Link, OFDM**

I. Introduction

Optical communications systems have evolved from lengthy fibers to powerful wireless system resulting in the use of optical wireless communication system in space communications. Laser communication technology is able to send information at data rates up to several Gbps and coverage of thousands of kilometers. This has opened up the idea to adapt optical wireless communication technology into space technology and hence inter-satellite optical wireless communication (IsOWC) came into being [1]. An inter—satellite optical wireless communications system offers a high bandwidth, small size, low power and low cost as compared to microwave satellite systems [2]. In addition, RF wavelength is much longer compared to lasers hence the beamwidth that can be achieved using lasers is narrow than that of the RF system. This result in lower loss compared to RF [3].

IsOWC can be used to connect one satellite to another, whether the satellite is in the same orbit or in different orbits. Commonly used orbits for satellites to revolve around Earth are LEO, MEO and GEO. A highly accurate tracking system is required which involves the use of beacon signal on the one side and a quadrant detector with tracking system at other satellite which ensures that the connected satellites are well aligned and have proper line of sight. To meet this requirement, the satellites use the Ephemerides data for rough pointing and a tracking system for fine pointing to the other satellite [4]. Several satellites have been developed with OWC inter—satellite links such as European Space Agency (ESA)'s Artemis and Japan's Kirari satellites [5-6]. IsOWC proves to be a better alternative for transmission of data at high rates but various parameters need to be taken into account which degrades the system performance [7-10]. The decrease in received signal causes the SNR to decrease which tends to increase BER.This problem is overcome by either increasing the transmitted power or decreasing the receiver noise. But, with the increase of power, major problems like high energy consumption, large weight and size of the satellite, high cost and complexity in system arises [11]. Hence, a very small transmitter divergence angles are used to assure maximum received power which eliminates the problem of power dissipation. A phased array based telescope is used to achieve minimum BER. But, due to use of very narrow beam, the transmitter may sometimes miss the receiver satellite due to pointing vibrations. Therefore, for small divergence angles, the transmitter optics having large aperture is required [12-13].

This paper is an attempt to optimize the ISL link between two satellites with acceptable SNR by incorporating OFDM technique. The OFDM technique distributes the data over a large number of carriers that are spaced apart at precise frequencies with overlapping bands. The use of FFT for modulation provides orthogonality to the subcarriers, which prevents the demodulators from seeing frequencies other than their own. Hence, by incorporating OFDM, IsOWC system can be used for optimizing the ISL links at very high data rates. Based on OFDM technology and optics, IsOWC system can construct high-speed, large-capacity and low-cost ISL links [14]. Also, its channel capacity is highly scalable, allowing smooth up-gradation or transition from existing networks. Moreover, OFDM-IsOWC system can not only reduce fading of wireless signals, but also improve signal quality. The feasibility of OFDM as modulation technique for a RoF based WLAN system has been investigated to carry 20 Mbps data, using carrier frequency of 2.4 GHz and prolonged the fiber length from 10 Km to 50 Km [15]. A conventional IsOWC has been demonstrated with at 2.5Gbps up to ISL link of 1000Km. This work is further extended by signifying of a hybrid OFDM—IsOWC system in this work to optimize the ISL link with acceptable SNR and minimum BER, which is not achieved in previous research work [16].

II. Model Decription

The OFDM-IsOWC system consists of three main communication parts which are transmitter, propagation channel and receiver which shown in Fig.1 where the transmitter is in the first satellite and the receiver is in the second satellite. The IsOWC system is not much different from free space optics and fiber optic communication where the difference relies in the propagation medium.The free space between two connecting satellites is considered as OWC

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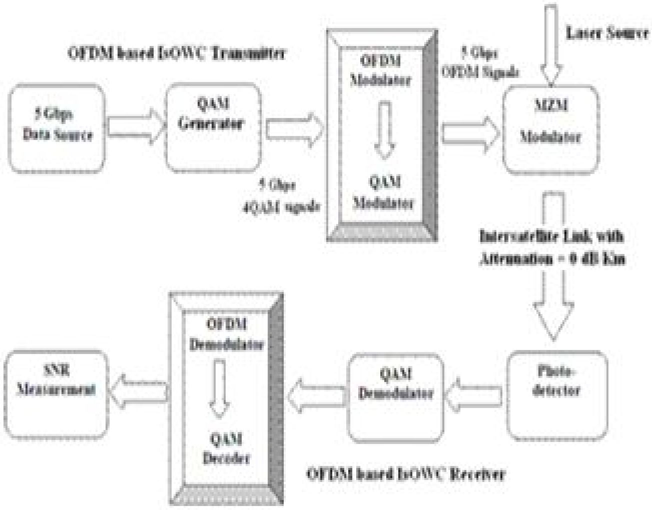

Fig. 1. Design of Hybrid OFDM-IsOWC System.

channel which is the propagating medium for the transmitted light. In the proposed OFDM-IsOWC, 5Gbps QAM data signals are generated using 4QAM sequence generator with 2 bits per symbol. These 5Gbps QAM data signals are then OFDM modulated by means of OFDM modulator using 512 subcarriers and FFT size of 1024 to generate 5Gbps OFDM analog data signals which, further, QAM modulated at 7.5GHz modulator frequency. This 5Gbps QAM-OFDM treated analog data signals are then transmitted by means of a CW laser of 0dBm. These OFDM signals are transmitted over OWC channel, considered to be outer space, where it is assumed to be a vacuum and free from atmospheric attenuation factors. Therefore, the free space loss is taken as 0 dB/Km of optical wireless channel in our proposed model. The OWC channel is modeled between the two satellites with different aperture diameter of optical antenna at each end to simulate optimized divergence angles to achieve high receiving power [14-15]. The transmitter and receiver gains are 0dB. The transmitter and receiver antennas are also assumed to be ideal where the optical efficiency is equal to 1 and there are no pointing errors. Additional losses from scintillation and mispointing are also assumed to be zero. In this work, the only cause of signal attenuation is the distance of the transmission. The receiving end of the IsOWC system consists of a photo-detector and a low pass filter.

III. Result Discussion

In this section, we have discussed the results obtained from our simulative setup consisting of optical OFDM analog data signals at 2.5Gbps and 5Gbps modulated at 7.5GHz QAM—modulator—frequency. This QAM-OFDM treated analog data signals are modulated with laser operating at different wavelengths. Then, it is directly transmitted over an ISL link by means of transmitting antenna of different aperture diameters. Firstly, SNR and total received power is calculated at different operating wavelengths with Tx = 15cm and Rx = 15cm as shown in Figure 2. From Figure 2 (a, b), it is observed that an improvement of 6dB in SNR is achieved with 1550nm as compared to 850nm. Secondly, the ISL link of 4000Km at 5Gbps and 5000Km at 2.5Gbps is achieved with acceptable SNR of 20dB. Consequently, the total received power at photo detector at 5Gbps is computed as -81dBm at the ISL link of 4000 Km and at ISL link of 5000Km at 2.5Gbps. The total received power at satellite 2 is improved by 4dBm in both the case but at the ISL link of 4000 Km with 5Gbps and at ISL link of 5000Km at 2.5Gbps as shown in Figure 2 (c, d) with acceptable BER. Further, the proposed OFDM—IsOWC system is investigated under the impact of aperture diameter of transmitting antenna at fixed Rx = 15cm.

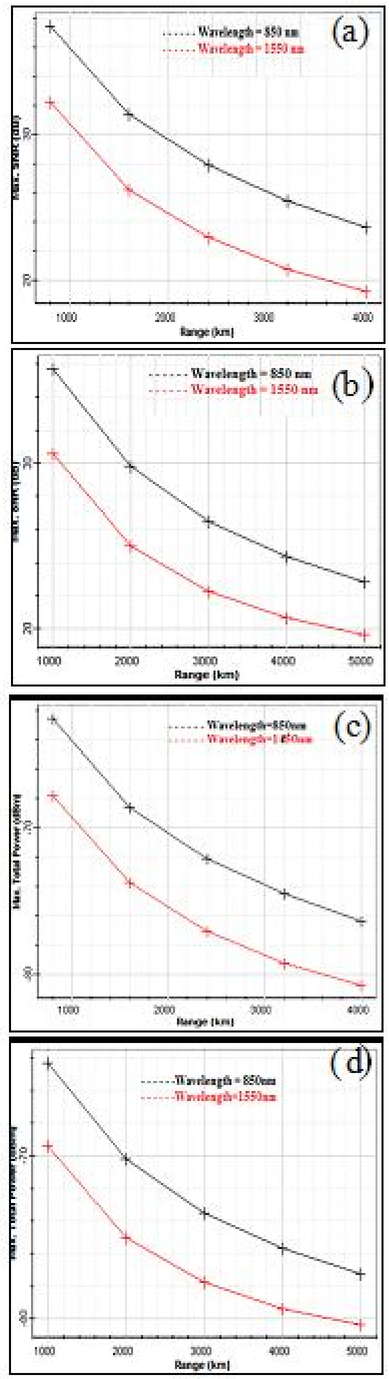

Fig. 2. SNR and Total received power via ISL at (a,c) 5 Gbps and (b,d) 2.5 Gbps with Tx = 15 cm amd Rx = 15 cm.

It has been observed that on doubling the size of aperture

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diameter of transmitting antenna, the ISL link has been lengthened to 8000Km at 5Gbps and to 10000Km with Tx = 50cm respectively with acceptable SNR of 20dBm as shown in Figure 3 (a, c). Also, the total received power at satellite 2 is computed as -79dBm with Tx = 30cm and -78dBm with Tx = 50cm at the ISL link of 8000 Km respectively and at ISL link of 10000Km as shown in Figure 3 (b, d) with acceptable BER.

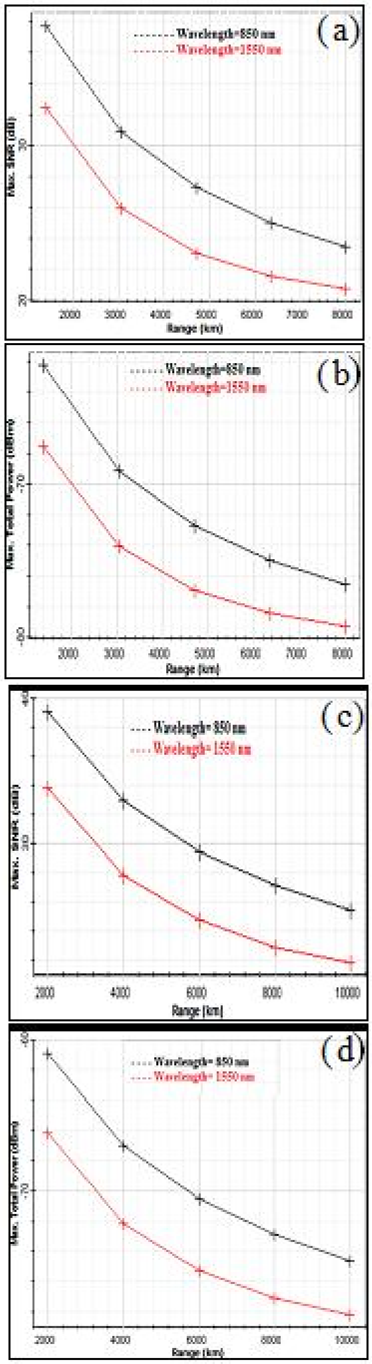

Fig. 3. SNR and Total received power via ISL Link at 5 Gbps with (a, b) Rx = 30 cm and (b, d) Rx = 50 cm with Tx = 15 cm.

Also, the proposed OFDM-IsOWC system is investigated at varied values of aperture diameter of receiving antenna at fixed Tx = 15cm. It has been observed that on doubling the size of aperture diameter of receiving antenna, the ISL link has been lengthened to 6000Km at 5Gbps and to 8000Km with Rx = 50cm respectively with acceptable SNR of 20dBm as shown in Figure 3(a, c). Also, the total received power at satellite 2 is computed as -79dBm with Rx = 30cm and -78dBm with Rx = 50cm at the ISL link of 6000 Km and at ISL link of 8000Km respectively as shown in Figure 3 (b, d) with acceptable BER.

Conclusions

A significant improvement in SNR along with acceptable BER at different data rates is achieved along with the maximum length of ISL link between the two satellites by incorporating OFDM scheme in IsOWC systems than that of conventional IsOWC systems [16]. It is also revealed out that not only the operating wavelength but also the aperture diameter of transmitting- and receiving antenna plays an important role in prolonging the ISL link with OFDM scheme in IsOWC systems.

References

[1] A. H. Hashim, "Modeling and performance study of inter-satellite optical wireless communication system", International Conference on Photonics (ICP), IEEE, pp.1–4, 2010.

[2] M. A. Krainak, "Inter-satellite communications optoe-lectronics research at the Goddard Space Flight Center", Aero-space and Electo-system Magazine, IEEE, vol. 7, pp.44–47, 1992.

[3] Chan, V.W.S, "Optical Satellite Networks", Journal of Light wave Technology", vol. 21, pp. 2811–2817, 2003.

[4] S. Arnon and N. S. Kopeika,, "Laser satellite commu-nication network-vibration effects and possible solutions", Pro-ceedings of the IEEE, vol. 85, pp.1646–1661, 1997.

[5] Z. Sodnik, B. Furch and H. Lutz, "Free-Space Laser Communication Activities in Europe: SILEX and beyond", Lasers and Electro-Optics Society (LEOS), IEEE, pp.78–79, 2006.

[6] C. C. Chen and C. S. Gardner, "Impact of random pointing and tracking errors on the design of coherent and incoherent optical inter-satellite communication links", IEEE Transactions on Communication, vol. 37, pp: 252–260, 1989.

[7] S. G. Lambert and W. L. Casey, "Laser communication in space", Journal of Applied Optics, vol. 37, pp.41–65, 1998.

[8] D. K. Paul and et al, "Optical inter-satellite links: Application to commercial satellite communications", In 14th AIAA Interna-tional Communication Satellite Systems Conference, Washington, pp. 277–289, 1992.

[9] Dyne, P. P. Collins, and D. Tunbridge, "Satellite mechanical health monitoring", Advanced Vibration Measurements, Tech-niques and Instrumentation for the Early Predication of Failure, IEE Colloquium, pp. 4/1– 4/8,1992.

[10] S. Arnon and N. S. Kopeika, "Adaptive bandwidth for satellite optical communication", Optoelectron, IEE Proceeding, vol. 145, pp.109–115,1998.

[11] K. Inagaki and Y. Karasawa,"Ultra high speed optical beam steering by optical phased array antenna", Proceeding SPIE Free Space Laser Communication Technologies VIII, vol. 2699, pp. 210–217, 1996.

[12] W. M. Neubert, W. R. Leeb, and A. L. Scholts, "Experi-mental results on an optical array antenna for non mechanical beam steering", Proceeding SPIE Free Space Laser Communication Technologies IV, vol. 1635, pp.82–89,1992.

DOI: 03.LSCS.2013.1.525

[13] J. E. Mitchell, "Performance of OFDM at 5.8GHz using radio over fiber link", Electronics Letters, vol no. 21, 2004.

[14] R. Prasad, "OFDM for Wireless Communications Systems",Artech House Publication, 2004.

[15] Yunazar, Ferdian, "Modeling and performance analysis of the OFDM scheme for radio over fiber system", Master's thesis, University Teknologi Malaysia, Faculty of Electrical Engineering, 2009.

[16] V. Sharma and N. Kumar, "Modeling of 2.5Gbps-intersatellite link (ISL) in inter-Satellite optical wireless com-munication IsOWC) System", Optics Communication, Elsevier, vol. 286, pp.99–102, 2013.

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